A YOLO-Tesseract Module Recognizing System for an Android-based Smart Parking App in Urban On-Street Parking

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ABSTRACT

This study describes an advanced recognition system embedded in an Android smart parking software application for Makassar City. The system augments the recognition of the parking space and the navigation as well as the payment of the parking fee using a Tesseract OCR module in conjunction with YOLO object detection. The ability of Tesseract OCR to recognize parking spaces, road signs, and vehicle registration plates in real time improves the accuracy of availability updates and assists drivers in finding parking spaces quickly. The application was developed using multiple programming languages, Android Studio, and API integrations for real-time data updates and payment transactions. Iterative testing, including black-box evaluations, ensures cross-device reliability, functionality, and ease of use. Experimental results demonstrated the system's effectiveness in optimizing parking resource utilization. Additionally, user feedback mechanisms refined the app for an evolving user experience. In conclusion, the YOLO-Tesseract recognition system represents a robust solution to urban parking problems. Its core model to improve on-street parking management can be scaled to smart city models worldwide.

Keywords-Android; IoT; mobile app; on-street parking; smart parking

I. INTRODUCTION

Although urban populations and vehicle numbers continue to increase worldwide, the ability to provide adequate parking remains one of the challenging issues in cities [1]. Makassar, Indonesia has increasing problems with on-street parking, where, almost daily, drivers face limited availability and accessibility [2]. Smart parking solutions allow optimization of parking resources and mobility [3]. This study introduces an Android-based smart parking application designed specifically for the urban environment of Makassar [4]. Designed to ensure better parking management, this application employs real-time data, ease of use, and sophisticated algorithms to increase efficiency [5]. The system can reduce congestion, enable easier parking, and solve other contemporary urban challenges.

On-street parking in Makassar has its own set of challenges due to high vehicle ownership rates [6, 7]. Recently, several studies focused on smart parking, most of them portraying off-street parking while neglecting special impediments related to the features of on-street parking, such as changing demand and limited space [8]. There are many smart parking apps, but they have low or no real-time data accuracy, preventing drivers from obtaining such information effectively [9]. Many problems arise due to the lack of seamlessness in digital payment and

delays [9-12]. This highlights the need for adaptive solutions to present real-time parking status, simple payment options, and easy navigation tailored for on-street parking in urban areas such as Makassar. The main limitation of smart parking systems in all Indonesian cities lies in the scarce research materials [13], as only a few studies have focused on specific design requirements [14], end-user requirements [15], and technical challenges [16]. Therefore, the absence of relevant works hinders city-specific workable solutions.

A smart parking system must be accessible to all users while offering friendly interfaces, practical operation, and low cost. This study set vehicle license plate recognition software as its main objective to achieve design excellence for Android-based devices in Makassar and throughout Indonesia. This study investigated improving urban parking management by creating a cost-effective technology-based solution that considers user accessibility.

As urban parking in Makassar faces various operational challenges, this study addresses issues related to usability, accessibility, and practical implementation. The social and economic circumstances of the city require critical attention because its street parking remains under Parking-Attendant (PA) control. Most PAs generate their main income through parking collections, as they typically belong to low-income groups. Implementing any smart parking solution requires features that make it easy to access and maintain, while also suitable for actual deployment [17].

In [18], a PC or laptop-operated smart parking system was proposed. However, its functional design needs important practical adaptations to work effectively in an operational parking environment. The main issue with the proposed smart parking system emerges from its dependence on WiFi, as many parts of Makassar experience inconsistent networks, leading to varying connectivity levels and changing speed capabilities. The requirement for PC-based control mechanisms creates operational challenges because PAs usually cannot use these devices, making system operation difficult. On-street parking scenarios are inappropriate for this solution due to its excessive hardware complexity combined with its large number of components. The implementation of this model attempted to replicate a complete parking station in a field, which is inappropriate in flexible urban parking conditions.

In [19], an Android-based smart parking system was proposed to improve certain deficiencies of the system in [18]. Shifting operations from PCs to smartphones made the system easier to access and more portable [19]. Multiple implementation obstacles affected the daily applicability of the system despite its availability. Users could view empty parking spaces within the system, but the verification process required physical examination using STNK documents along with user membership cards. The manual verification process resulted in performance degradation, as attendants needed to verify users with physical documents in addition to performing on-site checks. The system served as a monitoring instrument since it did not include an integrated payment system. The system operated without digital transaction features, making it impossible to provide a streamlined solution for on-site parking operations.

This study examined the aspects necessary to develop an operational and practical smart parking system while addressing the limitations of previous studies. The proposed parking system allows PAs to use it easily while offering automated features and secure digital payment methods with minimal manual verification tasks to provide users with enhanced convenience. This system pays great attention to transaction security along with data protection to meet current technological requirements and regulatory standards. The proposed smart parking system aims to meet the urban requirements of Makassar City, bridging the gap with an Android-based smart parking application. Other key functionalities include real-time parking space availability display [20], navigation to available vacant spaces [17], digital cash payments [21], and user feedback to realize constant improvements [22]. This solution aims to facilitate the parking experience by decongesting [23] and sustainably improving the general urban mobility system [24].

II. SYSTEM DESIGN

The proposed parking system was created using a mix of programming languages, such as Python and JavaScript, and frameworks, such as Flutter and Laravel, along with CSS and SQL integration in Bootstrap 4 stylesheets. It focuses on a parking network that connects to cloud-based APIs for data management and backend oversight. The system includes features for tracking locations and managing user roles to process parking data along with handling transactions and detecting geolocations effectively. It allows real-time identification of vehicles through an Android app equipped with a computer vision system that categorizes vehicles as motorcycles or cars. In addition, Optical Character Recognition (OCR) is employed to recognize license plates. The captured information is saved on servers for monitoring and verifying payments. PAs manage the parking system using an online control panel that includes customer registration and parking duration tracking. Customers have the flexibility to pay using options such as cash, e-wallets, and NFC-enabled electronic payment methods linked to a payment provider.

Once the payment is verified, the system updates the database and the user can exit the parking area. Upon arrival, the application detects the user's location, checks the availability of parking spots, and allows the user to pay through a payment option. The duration of parking and the fees charged depend on the type of vehicle and the time it stays in the parking area. The system consists of three actors, users, drivers and administrators, each with specific roles in registration, validation, management of parking sites, and payment processing. Administrators manage parking configurations, generate levy reports, and predict future parking demands.

The main contribution of this study is the use of image recognition for automated vehicle identification to improve system efficiency. A set of vehicle images, captured in different conditions, was collected to train the recognition model appropriately. The images were manually labeled to classify vehicle types and license plate numbers so that the model is reliable in real applications.

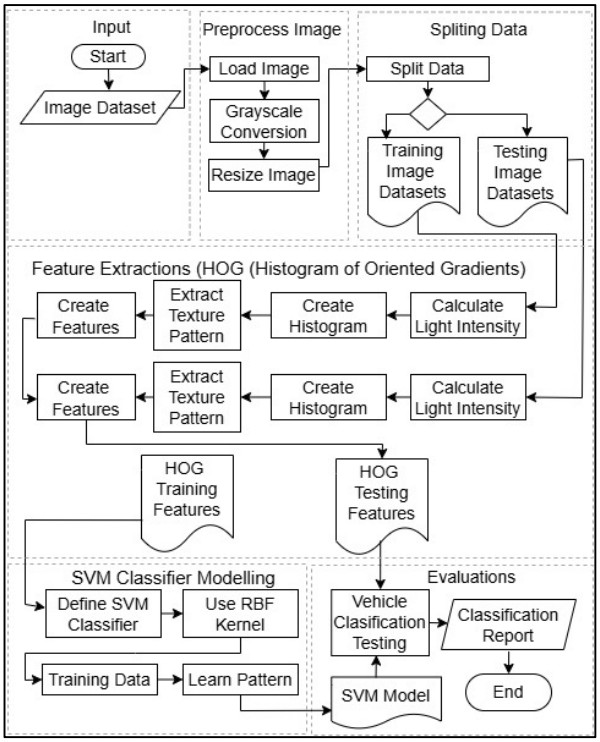

Fig. 1. System flowchart.

Image preprocessing was the initial phase of system development, which refined the acquired vehicle images by resizing, reducing noise, and converting them to grayscale format to enhance their quality before analysis. Motorcycle images were captured from positions one to two meters away. Car images were captured three to four meters away. For each object, the left and right views of its front side were captured, along with the rear side. All images were transferred to Google Drive before being categorized into different folders for motorcycles and automobiles. Data preprocessing enhanced image quality by reducing inconsistency and eliminating noise, maximizing computational efficiency. 290 images, consisting of 145 images of cars and motorcycles each, were taken in a parking lot in Makassar using a mobile phone camera with a 32 MP camera sensor at a 45° angle. The data was divided into training and test subsets in an 80:20 ratio. The Histogram of Oriented Gradients (HOG) function was used as a feature extraction method to enable the identification of distinctive form features and edge patterns to separate motorcycles from cars. HOG functions through the division of images into small connected regions, analyze edge orientations and gradient directions in them. A set of concatenated histograms forms an HOG descriptor that shows superior performance against geometric and photometric transformations, thus being appropriate for vehicle classification systems. Finally, a Support Vector Machine (SVM) model was used to correctly classify vehicles according to their defining features.

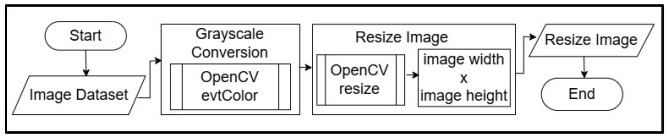

Fig. 2. Image preprocessing flowchart.

After training, the model was embedded in the smart parking application. The system was extensively tested with an accuracy examination of the trained model to determine its ability to correctly identify vehicles and license plates, followed by user acceptance examinations carried out by parking lot operators and vehicle owners to evaluate user-friendliness and operational performance. YOLO V8 was trained using annotated images with visible license plates to detect them under varying lighting conditions as well as vehicle angles and positions. The OCR functionality of Tesseract complements the system by extracting numeric characters from identified license plates to obtain the registration information. This dual-application method improves the reliability of automated vehicle identification systems.

The classification system uses SVM with an RBF kernel to create vehicle attribute mappings. The model retains information about the learning patterns collected. The HOG standard extracts vehicle-type data arrays from motorcycles and cars that form the input features. SVM classifies vehicles by analyzing value-differentiating features. The model was tested using new vehicle images to assess its predictive accuracy, using standard classification metrics, along with reliability results. Such performance indicators evaluate the model's capacity to distinguish motorbikes from cars, validating the system's readiness for practical deployment. The model was trained using various vehicle images under diverse real-life conditions leading to reliable performance. The evaluation process refined the machine learning model along with the complete system to improve accuracy levels and user satisfaction.

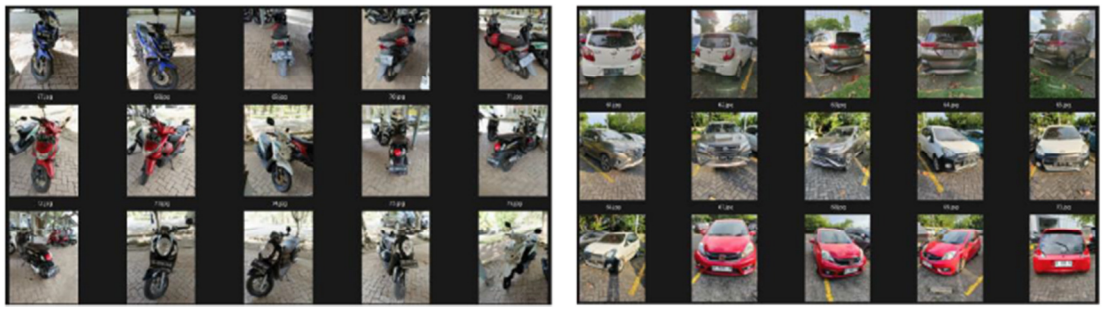

Fig. 3. Objects for recognition.

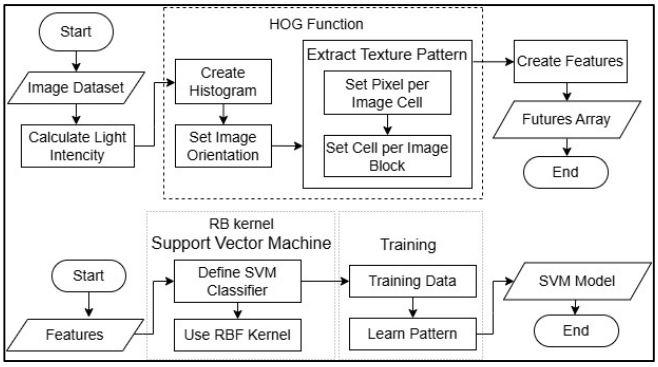

Fig. 4. HOG extraction flowchart and SVM architecture.

III. PROCESSING

The first step involved importing required modules and the use of Ultralytics YOLO for object detection and CV2 for image processing along with Pytesseract for OCR. The regex functions served to improve the quality of textual data extracted from recognized plates. During the preprocessing stage, all Indonesian vehicle license plates were transformed to grayscale to eliminate color differences, achieving superior recognition results. The system allows users to upload images, which activates YOLO detection to locate and extract the license plate area. An algorithm draws bounding boxes on the detected license plates before extraction to keep processing focused on the relevant section of images during character recognition. A looping procedure enables the system to process multiple detected plates, handling diverse events efficiently. The isolated license plate enters the processing stage after the cropping operation. Blurring simplifies text characters and makes them more readable for the OCR engine. The conversion to binary format through thresholding ensures the clear separation of characters from background elements. The OCR engine receives exact input from contour detection procedures that extract separate characters from the image.

Fig. 5. License plate and error detection.

The process converts the recognizable text characters from the image into a text string. A function converts the acknowledged character elements into an organized string format to produce a standardized output. High detection accuracy and plate text recognition were achieved. However, sometimes "0" was read as "G". The misidentification between 0 and G probably stems from training dataset limitations and visual character similarities or preprocessing defects. System errors can be reduced by expanding training data with various challenging character types along with improved preprocessing and examining different classification approaches from conventional OCR. Future enhancements can enhance both accuracy and reliability when used in actual vehicle identification systems.

IV. RESULTS AND ACCURACY

Field tests showed that the smart parking application worked correctly for administrators, PAs, and members of the system. The effectiveness of the system became evident through accuracy and F1-score metrics, indicating its value for real-life use. Black-box testing allowed for the assessment of different system components by replicating user behavior while verifying output responses without studying the code structure inside the black box. The chosen testing method ensures

application reliability, high usability, and accuracy when used across various operational conditions.

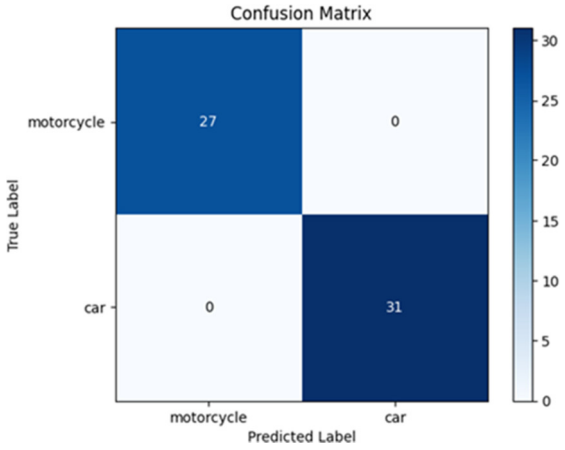

Fig. 6. Confusion matrix.

TABLE I. CLASSIFICATION RESULTS

Class	Precision	Recall	F1-score	Support (data)
Motorcycle	1.00	1.00	1.00	27
Car	1.00	1.00	1.00	31
Accuracy			1.00	58
Average	1.00	1.00	1.00	58

The results of YOLOv8 training with 25 epochs indicate that there was no overfitting. Precision, recall, and mAP remained high across training and testing, recognizing objects in the form of vehicle plates very well.

TABLE II. YOLO TRAINING RESULTS

Testing	Precision (P)	Recall (R)	mAP@50	mAP@50-95
Training set	0.98	0.982	0.993	0.888
Validation set	0.993	0.964	0.994	0.891

The system allows the administrator to perform effortless management of parking operations. After successful authentication, the login procedure routes users to the administration dashboard. Here, the administrator can handle all parking data while managing parking managers, and verifying members, active and inactive attendants, customers, and parking locations. All features in the dashboard execute their tasks without any issues between addition, editing, and record deletion functions. The system allows configuration for payment settings, and collector and attendant sites. Users can access precise financial information through the levy report and profit summaries, and document their reports in PDF format.

Through the system, PAs have an effective workflow solution to manage parking requests. The system successfully manages the login and registration methods, requiring user account verification to gain system access. The parking point maps present accurate member demand information and provide attendants the ability to take vehicle images at parking spaces while confirming registration information. The payment processing system accepts three payment methods, which include cash, wallet payments, and card transactions. The system sends notifications for new parking requests and payments to attendants, while the history page keeps complete transaction records. Profile management shows proper functionality that allows staff to change their profile information.

The user account subsystem executes its functions without any issues. Users can easily perform both login and registration to access system features. The system displays precise parking point maps to show currently available spots, as the "Navigate Me" function guides users to their selected parking areas.

The parking system was tested simultaneously at 9 locations for 8 hours of operation. The system ran well in performing parking activities well with the parking application. Table III shows data on parking locations and 827 vehicles in total spread across 9 parking locations.

TABLE III. SYSTEM TEST LOCATION AND SUBJECT COUNT

	Parking Locations	Motorcycles	Cars	Subtotal
1	Civil Engineering Building, Faculty of Engineering Hasanuddin University	63	19	82
2	Centre of Technology Building, Faculty of Engineering Hasanuddin University	2	13	15
3	CSA Building, Faculty of Engineering Hasanuddin University	55	29	84
4	Geology Engineering Building, Faculty of Engineering Hasanuddin University	40	3	43
5	Naval Engineering Building, Faculty of Engineering Hasanuddin University	84	7	91
6	Electrical Engineering Building, Faculty of Engineering Hasanuddin University	35	7	42
7	Classroom 1 Building, Faculty of Engineering Hasanuddin University	122	9	131
8	Classroom 2 Building, Faculty of Engineering Hasanuddin University	134	14	148
9	Mechanical Engineering Building, Faculty of Engineering Hasanuddin University	163	28	191
	Total	698	126	827

After leaving a parking space, users receive a complete breakdown of the billing data, which includes the parking spot details along with vehicle information, elapsed time, and payment amount. Users have various options to pay through the payment system, which provides effortless transaction capabilities. Users receive parking updates through notifications, while the e-wallet shows their account balance along with the record of transactions. The device successfully performs profile management along with secure e-wallet pin change functionality, providing convenient service. The system achieves its purpose outstandingly due to its precise operations and efficient execution when performing smart parking management tasks. A reliable endpoint connection to the VPS server in combination with the classification system provides a foundation for a powerful solution that expands in capacity. The research findings confirm the appropriateness of deploying advanced parking management technology, which advances smart city development in Makassar. The system should undergo further development to enhance precision, increase OCR capabilities, and add features to meet evolving user requirements.

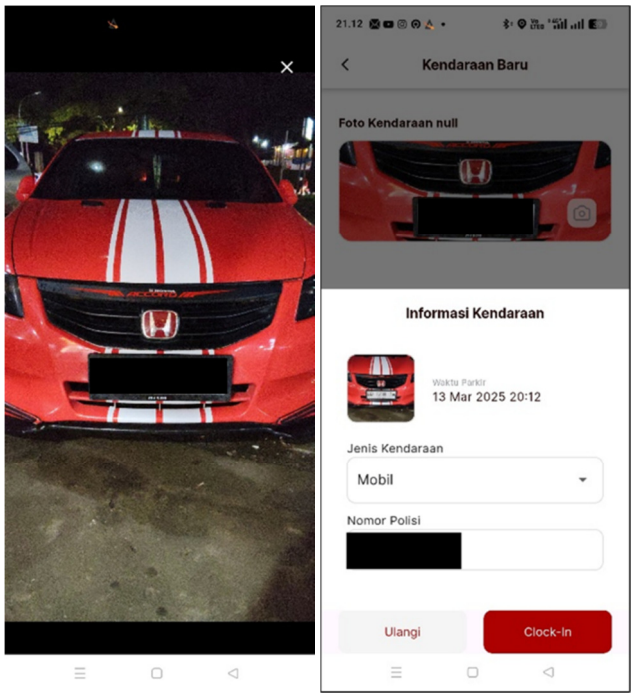

Fig. 7. App UI successfully identifying a car.

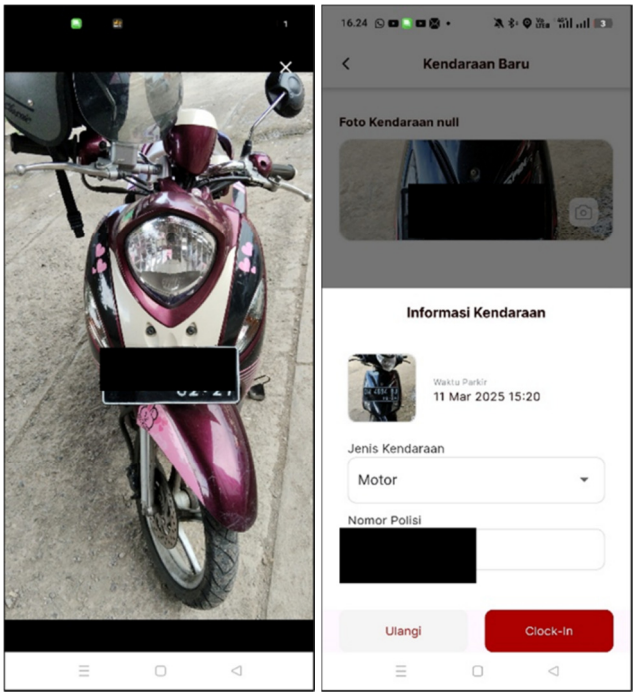

Fig. 8. App UI successfully identifying a motorcycle.

The proposed smart parking system (Parkirta) has built-in integration capabilities to connect to transmission systems for traffic management and improve urban safety and mobility. An API enables seamless data transfer between Parkirta and the current transportation infrastructure, making integration possible. Parkirta, coupled with traffic management platforms, allows officials to route vehicles to open parking slots, preventing unnecessary traffic circles and congestion in busy zones. Numerous public agencies could benefit from ITS integration with Parkirta, providing predictive analytics on parking demand to optimize urban planning and road space usage. An integrated system would address Makassar's problems with manual attendants, following a structured approach to space allocation, allowing dynamic pricing and real-time congestion-based monitoring for better efficiency. Parkirta achieves effective urban policy standards by integrating digital payments. The system implements encryption for data transfer combined with authentication protocols to ensure both safe payments and user data protection. Parkirta presents itself as an operational platform that adapts to upcoming advances in smart urban transportation with specific essential features.

The system features separate user access privileges for data privacy purposes, so only necessary parking-related tasks can be performed. An operating closed-loop network provides distinct access requirements for various roles to protect security and avoid illicit monitoring. Users can search for parking locations after registering through the login procedures and can reserve spots before occupying them using their top-up balances or cash payments. The system allows PAs to perform tasks by managing parking areas and approvals for member access and payment processing with available payment options. Through their oversight duties, collectors check registered attendants and supervise all active parking areas under their control. The task of verifying user accounts and parking cards belongs to member verifiers who work with e-money systems. The super admin possesses complete monitoring control, encompassing location activation and fee adjustment, as well as occupancy threshold setting and final authority over parking operational control. The system provides exclusive access to super admin location data, so members cannot track one another through the system. Each user receives access only to their unique account, preventing any unauthorized tracking of locations during operation. The system structure protects data privacy and operates effectively to maintain user information security for parking purposes.

Parkirta maintains the security of payment transactions using iPaymu as its payment gateway. iPaymu holds a PCI DSS certification, registered as 004433.01/DJAI.PSE/07/2022 under the Indonesian Ministry of Communication and Informatics. Thus, Parkirta demonstrates internationally recognized data security standards that guarantee the safe processing of every payment transaction. The fraud detection system of iPaymu detects irregularities in user account usage before a potential account misuse occurs. The system provides instant monitoring capabilities as well as immediate protective measures against fraudulent actions. All top-up operations are executed within the iPaymu database and simultaneously generate database changes through the Parkirta backend system for precise user account balance tracking. The combination of security measures enhances transaction safety, providing a reliable and protected payment service to all users of the Parkirta platform.

V. CONCLUSION

Through Parkirta, the Android-based application provides solutions to Makassar City street parking issues by combining real-time processing and intelligent algorithms with a user-friendly interface. The system streamlines parking operations while decreasing traffic jams and enabling contemporary urban transportation in compliance with smart city goals. Parkirta forms a modern digital solution that surpasses previous research with unrealistic hardware and manual verification, delivering a fully digital system specifically designed for local needs as well as accessibility and efficiency.

The Parkirta system is a Java/Android Studio project based on agile methods, with API-driven real-time functionality, digital payment capabilities through PCI DSS-certified iPaymu, and VPS-based endpoint for reliable data transmission. Black-box testing demonstrated that the system operates reliably on all devices and performs well, while its F1-score evaluation proves its precise vehicle recognition capability. Sustainable cities' development benefits from Parkirta through its efforts to improve expectations alongside digital developments. Further development will target better OCR functions along with improved vehicle recognition algorithms while adding new user-requested features to align with changing technological demands in urban transportation systems.

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